Oceanic Fluxes Across Arctic Gateways in the Regional Arctic System Model

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Abstract

Under the recent changing climate, the Arctic has experienced an amplified warming, with the declining of Arctic sea-ice being its key indicator. While global Earth System Models (ESMs) are generally in agreement with the observed sea ice trend, they are often limited in representing the acceleration of Arctic warming due to under-resolved physical processes and feedbacks especially critical in high-latitude regions. Those include the processes controlling the transport, distribution and accumulation of heat in the upper ocean and its interaction with the sea-ice and atmosphere. Such ESM limitations are likely due to a combination of coarse resolution and the fidelity of model physics. Which is why there have been growing efforts to increase model spatial resolution in order to explicitly resolve some critical physical processes, e.g., meso-scale eddies and coastal currents, bringing heat from sub-polar regions. However, due to limited observational data, it is hard to constrain modeled Arctic – Subarctic ocean fluxes or to improve parameterizations of processes controlling them. To underscore the necessity for such measurements, several numerical experiments are analyzed using the Community ESM (CESM) and Regional Arctic System Model (RASM) at varying spatial resolution. Here we focus on the oceanic volume/heat fluxes across the Arctic gateways to demonstrate the importance of local currents on the northward ocean heat transport.

1. The Regional Arctic System Model (RASM)

The Regional Arctic System Model (RASM) is a limited-domain, fully coupled, high-resolution atmosphere, ocean, ice, and land model. The primary components are the Weather Research and Forecasting (WRF3.7), Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP2) and Sea Ice Model (CICE6), and the Variable Infiltration Capacity (VIC) land hydrology model. These four components are coupled using the Community Earth System Model (CESM) coupler, CPL7 (Fig. 1a). The RASM domain includes the Arctic Ocean and surrounding marginal seas as well as the sub-Arctic North Pacific, including the Bering Sea, Sea of Okhotsk, and Gulf of Alaska, and the sub-Arctic North Atlantic, including the Nordic Seas, Labrador Sea, Baffin Bay and Hudson (Fig. 1b).

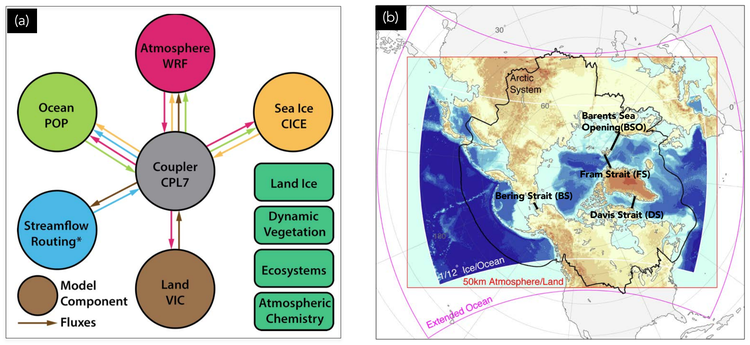


Fig 1. (a) RASM components and wiring and (b) RASM domain with bathymetry and terrain as color shading: BS, Bering Strait; BSO, Barents Sea Opening; DS, Davis Strait; FS, Fram Strait.

2. Model Simulations: 1980-2014

Case		CESM-LR	CESM-HR	RASM-1deg	RASM-9km	RASM-2km
Name (Experiment)		CESM1-CAM5-SE-LR (hist-1950)	CESM1-CAM5-SE-HR (hist-1950)	R2200tGcdaa01f (hindcast)	R2200rGcsph02f (hindcast)	R2300uGcspn01f (hindcast)
Arctic Ocean (>65 N) Horizontal Resolution Range: Min.-Max. (Mean)		7.8 ~ 72 km (45 km)	2.7~7.0 km (5.0 km)	7.8 ~ 72 km (45 km)	8.5 ~ 9.3 km (9.2 km)	2.1 ~ 2.3 km (2.3 km)
Vertical # of Ocean		60	62	60	45	45
Atm.-Ocean-Ice-Land Models (forcing)		CAM5.2-POP2-CICE4-CLM4		POP2-CICE6 (JRA55-do)		
Net Volume Flux (Sv=10^6 m^3/s)	BS	0.77	1.41	0.65	0.70	0.65
	BSO	1.91	4.04	0.70	2.89	2.59
	DS	-1.49	-2.79	-1.21	-1.72	-2.34
	FS	-1.18	-2.61	-0.14	-1.86	-0.86
Arctic Ocean Heat Convergence (TW)		64	196	54	116	104

Table 1. A summary of CESM and RASM simulations. Volume fluxes are estimated at the Arctic main gateways shown in Fig 1b; the positive values indicate the net flux into the Arctic and the negative out of the Arctic.

3. Fram Strait: Mooring Observations

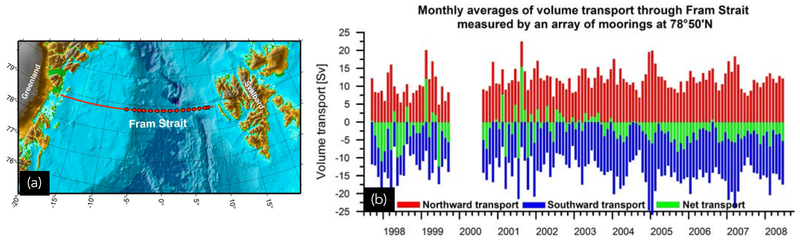


Fig 2. (a) Location of the Fram Strait mooring sites (•) between the Spitsbergen and Greenland shelf and (b) monthly mean estimates of measured volume transport through Fram Strait in 1997-2008 (https://iceobs.nersc.no/observations/temperature-salinity-and-volume-fluxes-in-the-fram-strait)

4. Fram Strait: Volume Transport

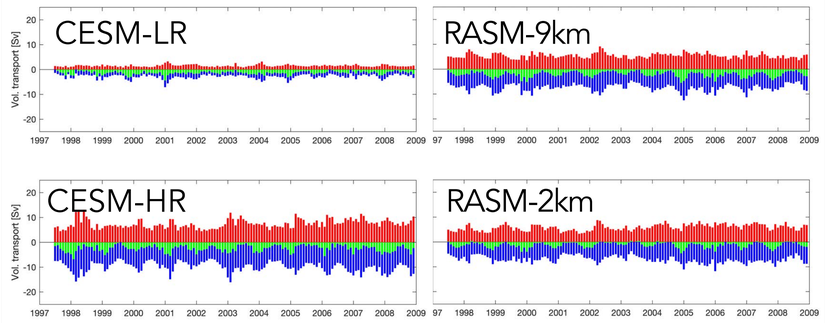


Fig 3. (left) CESM and (right) RASM volume transports (Sv, 10^6 m^3/s; red, inflow; blue, outflow; green, net) across Fram Strait in 1997-2008.

5. Bering Strait: Temperature and Velocity

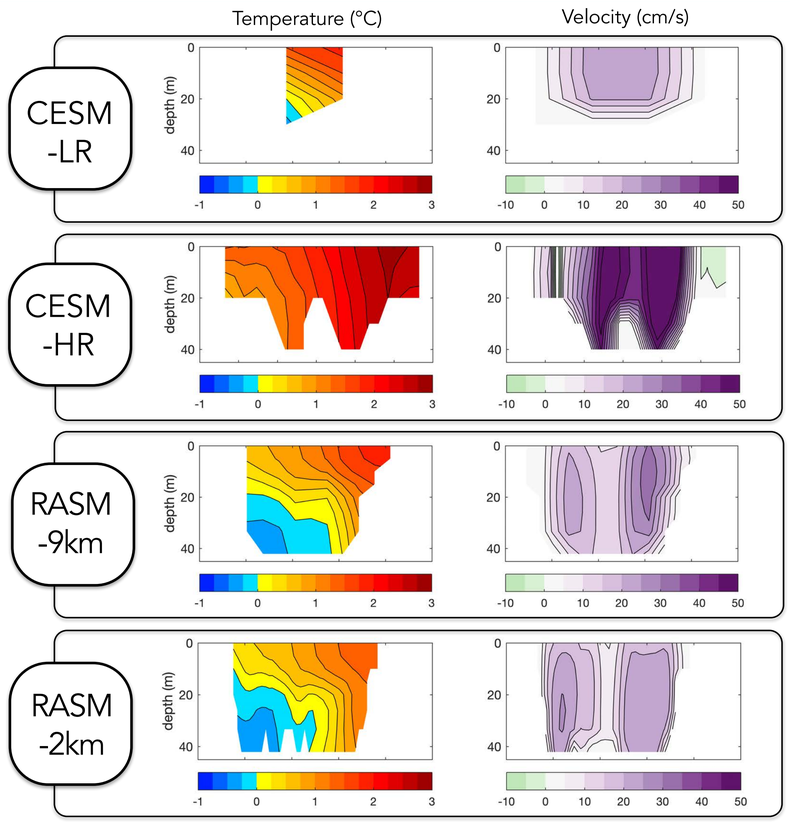
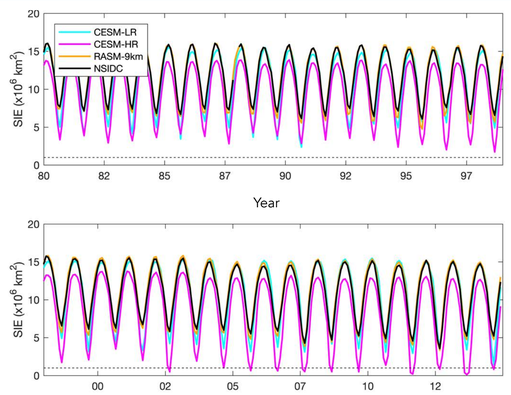


Fig 4. Long-term mean temperature profile (left panels) and cross-section velocity field (right panels; positive, in-to-the Arctic; negative, out-of-the Arctic) in Bering Strait from CESM and RASM simulations listed in Table 1.

7. Arctic Sea Ice Extent

Fig 6. Time series of monthly mean sea ice extent (SIE) estimates in the Arctic Ocean for the period of 1980-2014 from CESM and RASM simulations, comparing with the satellite-derived SIE estimate from National Snow and Ice Data Center (NSIDC; black). SIE is calculated by spatially integrating the areas where sea ice concentration is greater than 15%.



Summary & Future Research

- ❑ Net volume fluxes across the Arctic main gateways varies between the simulations; the higher resolution, the larger fluxes across the gateways.
- ❑ CESM high resolution simulation may overestimate heat fluxes into the Arctic since sea ice almost disappears during summer of 2002.
- ❑ The low resolution models exhibit lack of skills representing coastal currents such as Norwegian Coastal Current, which is critical to understand the connection between the Arctic and the sub-Arctic regions.
- ❑ Hence, improved observational flux estimates are necessary to constrain ocean and other climate models.
- ❑ Also, Arctic-wide balanced volume exchanges are needed across the gateways.

6. Barents Sea Opening: Volume and Heat Fluxes

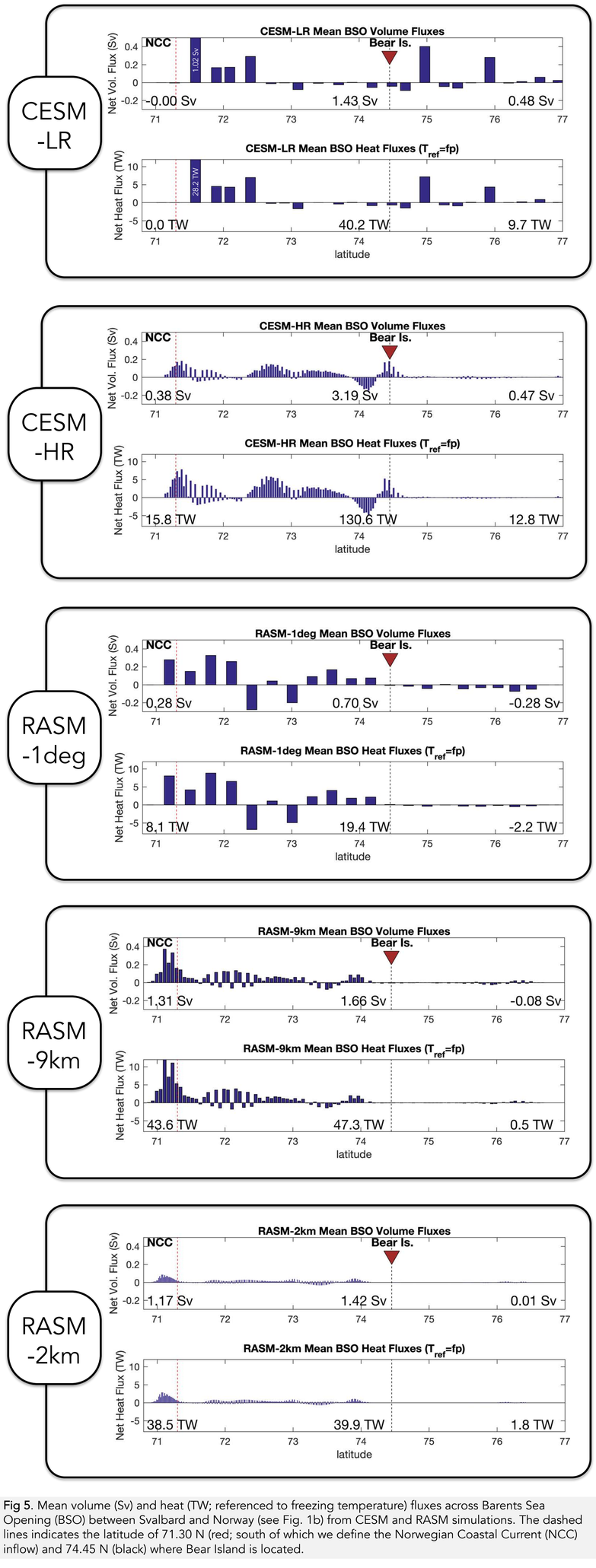


Fig 5. Mean volume (Sv) and heat (TW; referenced to freezing temperature) fluxes across Barents Sea Opening (BSO) between Svalbard and Norway (see Fig. 1b) from CESM and RASM simulations. The dashed lines indicates the latitude of 71.30 N (red; south of which we define the Norwegian Coastal Current (NCC) inflow) and 74.45 N (black) where Bear Island is located.

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